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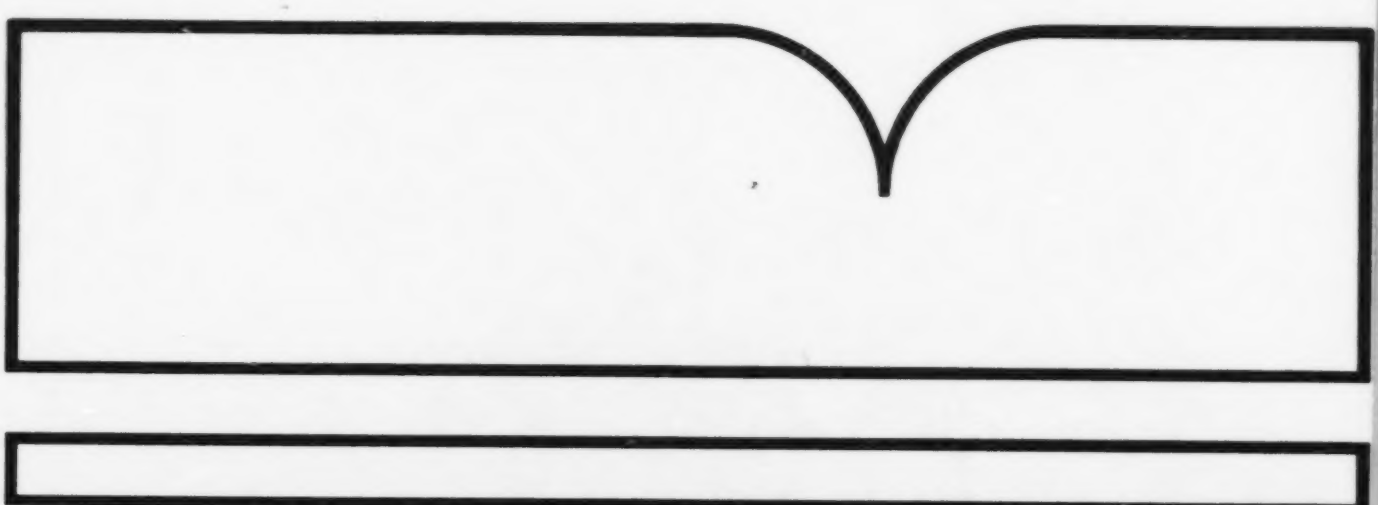

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16. ABSTRACT

This paper describes the status of the U.S. Environmental Protection Agency's program to develop dispersion models with demonstrated improved reliability for large sources in complex terrain. Due to finite resources, the initial effort focuses on modeling maximum one-hour concentrations on prominent terrain obstacles impacted by stable plumes. Workshop recommendations on the foregoing problem and other considerations in formulating a project plan are discussed along with the future direction of the program.

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THE EPA PROGRAM FOR DISPERSION MODEL DEVELOPMENT FOR SOURCES IN COMPLEX TERRAIN

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1. INTRODUCTION

Progress in modeling plume dispersion for sources in complex terrain has been extremely slow to materialize, although the problems have always been recognized. Hewson, after completing his classic investigation of the plume from the Trail, British Columbia smelter (Hewson and Gill, 1944), points out in his Compendium of Meteorology article (Hewson, 1951), the great uncertainties that are imposed upon calculations of dispersion over complicated topography. Although individual notable efforts have been made in recent years, the problem as a whole has remained, largely because of the expense of conducting full-scale experiments in complex terrain. But now projections of large-scale development of energy resources in the mountainous West, including proliferation of large coal-fired plants, and deep concern about environmental impacts are demanding the development of applicable dispersion models with demonstrated reliability.

Thus, significant commitments to work on problems of modeling dispersion for sources in complex terrain have been made by the Department of Energy (Dickerson and Gudiksen, 1980), the Electric Power Research Institute (Hilst, 1978), and the Environmental Protection Agency. Very briefly, the DOE Program currently is focused on the Geysers Geothermal Area in the rugged Coastal Mountain Range of Northern California. The investigation is concerned mainly with transport and diffusion of emissions at low heights in nocturnal drainage flows. The EPRI Program is concerned with the validation of plume dispersion models in current use and subsequent model improvement. A comprehensive measurement program is underway at a power plant in uncomplicated terrain and will be conducted successively at plants in coastal and mountainous settings. As I shall describe in detail, the EPA Program at this stage is focused on model improvement/development of stable plume impaction on elevated terrain. While each group has individual priorities, the ultimate objective of improving model credibility is common, and each has pledged to keep the others informed and to cooperate as much as possible.

2. THE EPA PROGRAM

2.1 Objectives of Initial Research

The EPA Program essentially is contained in a Request for Proposals (DU-80-B002), responses to which are currently in an advanced stage of evaluation. The Request focuses on the improvement of mathematical modeling capabilities to describe concentrations at ground level (i.e., at the 2-m height) on elevated terrain due to an elevated plume from a large source (e.g., a power plant) in a stably stratified atmosphere interacting with a terrain obstacle, i.e., stable plume impaction. This is our primary objective. The emphasis is on flow structure and diffusion characteristics in the immediate vicinity of the terrain obstacle. At this time our basic concern is <u>not</u> how a plume gets from its source to the immediate vicinity of an obstacle. This attitude has been taken by EPA because in the models [e.g., Valley (Burt, 1977) and CRSTR (EPA, 1977)] that currently are widely used to determine compliance with air quality regulations (e.g., national ambient air quality standards and prevention of significant deterioration) for sources in complex terrain, plume impaction has become a major controversy.

This emphasis is not made naively for we are well aware of the magnitude of the total problem, e.g., as described recently in the ERDA-sponsored, Albuquerque workshop on complex terrain research needs (Barr et al., 1977). That report estimated a total cost of 20-30 million dollars to be expended over 3-5 years for a comprehensive research effort. Clearly, the EPA is not able to commit such resources. Thus, we have focused on a particular aspect of the overall problem, an aspect of widespread concern that we believe can be resolved significantly within our available resources. This idea was presented at the convening of our EPA-sponsored workshop (Hovind, et al., 1979) on model development for sources in complex terrain. The workshop participants endorsed our plan and offered recommendations, all of which were not unanimous, on how best to achieve the objectives. Those recommendations were considered in developing our RFP.

Since the model(s) will be used extensively to test compliance with air quality regulations, it is important that they be reasonable to apply in terms of computer resources and required input data. But that doesn't mean that required meteorological data for complex terrain models should be the same as for flat terrain models. In general, to achieve the same reliability more data, and probably different kinds, will be required in complex terrain. We expect that from testing and validating the models, their reliability may be defined as a function of specific input information. In addition, the meteorological, topographical, emission, etc., conditions under which the models are applicable must be clearly defined.

The basic concentration time-period to be modeled is the 1-hr average. But as a secondary

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priority the contractor is required to consider the feasibility of extending/adapting the model(s) to calculate 3- and 24-hr average concentrations (in terms of some advantage over averaging 1-hr sequential values). Other secondary priorities are to evaluate the feasibilities of applying/adapting the model(s) to other terrain configurations (than those initially specified) and during neutral and unstable conditions. One logical extension of stable plume impaction to nonstable conditions is to the situation after sunrise as the nocturnal stable layer is eroded by surface heating.

2.2 Approach to Achieving Objectives

We perceive achieving our goals through an integrated and highly coordinated effort that involves (1) model evaluation/improvement/development, (2) scaled physical modeling in a fluid modeling laboratory, (3) field measurements/experiments centered on an isolated, simple hill of relatively small size (perhaps repeated at a different site), and (3) field measurements/experiments centered on a full-scale power plant that is located in the West in terrain with opportunities for plume impaction and other types of plume-terrain interactions. I emphasize that we expect the mathematical modelers to be active throughout all phases of the project; the individuals responsible for model development/production are expected to provide leadership throughout the program. The basic objective is not the collection of measurement data; it is the production of a useful model (or models) with demonstrated reliability and prescribed applicability. We expect the initial model improvements to follow Gaussian concepts with subsequent developments employing more advanced concepts, but recognizing the limitations for practical applications.

The EPA will provide scaled physical modeling support from its Fluid Modeling Facility (FMF) in Research Triangle Park, NC under the direction of Dr. William H. Snyder. Our FMF is equipped with a meteorological wind tunnel and a stratified towing tank. The type of support that our Facility will provide is exemplified in a recent outstanding report (Hunt and Snyder, 1980) that is highly pertinent to our anticipated program. The Facility has constructed a scale model of the site where we expect to conduct the small-hill study. Our FMF staff is prepared to begin interacting with the project modelers as soon as the Contract has been awarded. One of our objectives in this program is to demonstrate the applicability--and limitations--of laboratory scaled physical modeling measurements. While such experiments are not expensive, they are far more reasonable to conduct (without uncertainties of weather) than are field studies. And, by allowing the controlled variation of independent variables, laboratory experiments provide deeper insight and understanding of the fundamental physics, thus leading to construction of mathematical models that are at least correct in principle. Our expectation in anticipated extensions of our current complex terrain program is to make the greatest possible use of laboratory data on scaled physical models.

Besides model production, the other basic item in the scope of work is a two-phase field study centered on plume impaction on an isolated, simple hill of about 100 m in height. Our philosophy in keeping the initial field study relatively small and simple is essentially to provide a link between basic laboratory studies and the real atmosphere, and to enhance the success of the field measurements efforts. The first phase will be largely qualitative, employing visual tracers with photographic documentation. The visual tracer (e.g., smoke) will be released upwind of, on, and around the hill from pots, generators, or rockets as necessary to demonstrate pertinent flow and diffusion features. It is essential to release smoke upwind of the hill from different levels on a stable but mobile platform that preferably can be extended to the hill height. For example, it is important to know the release-level above which the plume does not impact the hill. Mobility of the tracer platform is necessary to react to unexpected changes in wind direction. The pertinent structure of the approach flow and the flow on/above the hill will be measured as deemed necessary to classify the observed smoke characteristics on the hill. Throughout the field studies we encourage the use of proven, reliable remote sensors and aircraft platforms as may be appropriate. A main objective of the first-phase, qualitative experiments is to provide insight/experience for design and conduct of the second-phase, quantitative experiments. But in addition, we intend to use the visual data to demonstrate to pollution "controllers" and to the "controlled" the reality of plume-terrain interactions that are being modeled. While primary attention throughout all phases of the field studies is on plume impaction, we expect that other related phenomena will also be studied as opportunities occur within budget and time limitations.

The second phase of the small-hill impaction study requires measurements of tracer release rates at the upwind release platform, tracer concentrations in the plume before it interacts with the hill, at the hill surface (2-m level), and in the shallow, turbulent boundary layer above 2 m. Additional meteorological measurements in the second phase will be made as deemed necessary to understand the flow and diffusion over the hill--and as deemed necessary by the modelers. The number of field experiments to be undertaken must be adequate to satisfy the modeler's needs for testing, development, and independent validation. As in the first phase, a visual tracer will be used also and pertinent phenomena will be documented photographically. During the overall period of both phases of the small-hill experiments the fixed meteorological measurement system will remain operational to provide data for a climatology of pertinent dispersion features on the hill.

We are convinced that success of the field studies will be enhanced markedly by real-time collection, processing, and graphical display of at least certain selected measurements. Similarly, all pertinent data should be processed and reviewed in time for planning the following experiment(s) (e.g., within 24 hr). We also believe that in terms of our primary interest in 1-hr average concentrations, the use of some data averaged over no more than 10 min will be essential for understanding and modeling important physical mechanisms. A very comprehensive data

management system, including reviews for errors and instrument status, and incorporation of calibration and quality control information, is required to provide the modelers with an early, reliable, up-to-date data base. Besides responsibility for an on-going comprehensive quality assurance program, the Contractor also is required to have quality assurance audits conducted by an independent organization--all meeting EPA requirements. All field activities and data must be thoroughly documented and ultimately the data archive must be provided to EPA in a form compatible with its UNIVAC 1110.

Although there is no assurance at this time, EPA may sponsor independent organizations (including government) who have specialized measurement techniques, services, etc., to participate in the field experiments. The Contractor is required to cooperate with them, to support them, and to integrate their data into the collection/archive system.

The Contract includes three options. The first option provides for a second small-hill field study about a year after the first one, after the modelers have had time to thoroughly study the results of the initial small-hill experiments and evaluate the merits of a second series of experiments. The second series may be conducted on the same hill that was used in the first series or the modelers may recommend a different terrain obstacle.

The second option calls for measurements and experiments much as in the small-hill studies, but centered on a full-scale power plant plume. This study would take place about 1 year after the last small-hill study. The Contractor is required to recommend a power plant located in the western United States in an area of complex terrain with ample opportunities for plume impaction and related plume-terrain interactions, as supported by meteorological data and analyses. While the main purpose of this part of the project is to provide full-scale data for development and testing of the stable plume impaction model, other important plume-terrain phenomena should be measured for consideration in extending the scope of model development. Measurements of power plant plume concentrations (e.g., SO_2) are required aloft and at the surface. In order to enhance the credibility of the modeling results, important plume phenomena will be documented photographically, using artificial visual tracers as necessary. In addition, quantitative tracer concentrations will be determined, aloft and at ground level, for releases at different heights so as to impact preselected terrain features. As described for the small-hill experiments, a comprehensive set of pertinent meteorological measurements will be provided as necessary to support the modeling effort. Fixed meteorological measurement systems will be kept in operation for about 1 year in order to provide data for development of a dispersion climatology. Hopefully, the climatology will be capable of inferring plume behavior, especially that addressed by the "improved" models.

The third option requires the Contractor to provide for a symposium at which the results of the total effort will be presented to the scientific community. Besides Contractor presentations we will encourage participation by other groups also engaged in complex terrain studies. Assuming that the first two options are exercised, the symposium would probably be held about 1½ years after the full-scale plume study.

2.3 Recommended Small Hill

Although the Contractor may recommend another small hill for the first field study, the EPA has found one that satisfies many of the expected requirements. Cinder Cone Butte is a roughly circular, twin-peaked, isolated hill; it is about 100 m high with a diameter of approximately 1 km as shown in Figure 1. It is located in the broad Snake River Plain, 50 km southeast of Boise and 25 km northwest of Mountain Home Air Force Base. The hill is on land administered by the Department of Interior, Bureau of Land Management, who has issued a use permit to the Idaho National Guard for field maneuvers. However, private land which is used for agricultural purposes extends up to the eastern base of Cinder Cone. The Federal Aviation Administration operates a 61-m tower on the northern peak of Cinder Cone as a microwave (radar) relay station. There is electrical power on the hill and a road to the top.

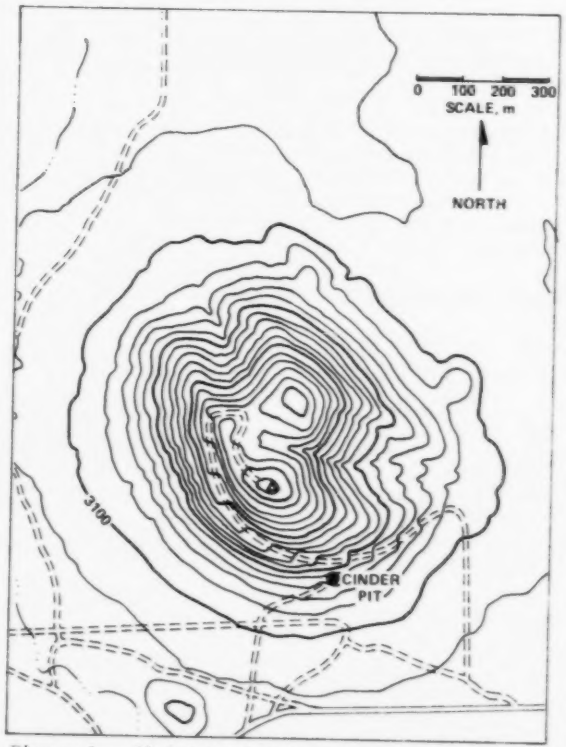

Figure 1. Cinder Cone Butte, Idaho. Contour intervals, 20 feet. Highest point, A, 3426 ft MSL.

Atmospheric stability at low heights, especially during nighttime, appears to be very common throughout the Snake River Plain. Based on surface weather observations at Mountain Home AFB, the most common wind directions are southeasterly and northwesterly, parallel to the general orientation of the Snake River. While morning around sunrise may at first seem the optimum

time to study stable plume impaction, the evening around sunset when stability begins to set in should not be overlooked. For a small hill such as Cinder Cone Butte, any tendency for local drainage winds around sunrise is likely to be overcome by the general drainage winds that develop throughout the night in the broad Snake River Valley. On the other hand, around sunset, in the interim between general daytime anabatic and nocturnal katabatic flows, may offer the best opportunity for local drainage winds on Cinder Cone Butte. We feel that such local drainage winds may be important in plume impaction. Because of the likelihood of undesirable weather, from an operational as well as experimental design viewpoint, winter and spring appear to be poor seasons in which to attempt field studies. Since greater stability generally is favored by longer nights, we believe that autumn is the optimum season in which to conduct field studies on Cinder Cone Butte.

2.4 Time Schedule

A tentative schedule of major events in accomplishing our objectives is depicted below. In case all options are not exercised, suitable adjustments will have to be made, as will be the case for unexpected delays. If it becomes possible to speed up the progress of the work, EPA will be more than pleased to do so. We will be pleased to make adjustments also, if it becomes feasible to join in cooperative studies with others such as DOE and EPRI.

Although not explicitly stated in the Schedule, the EPA Fluid Modeling Facility will be conducting experiments in support of the Contract modelers throughout the program. As already mentioned, we expect the Contract modelers to be active in all aspects of the program.

SCHEDULE FOR COMPLEX TERRAIN MODELING PROGRAM

JUN 1980.....AWARD CONTRACT.

OCT-NOV 1980..CONDUCT SMALL HILL IMPACTION STUDY NO. 1.

JUN 1981.....PRESENT MODELING CONCLUSIONS BASED ON FIELD AND LABORATORY EXPERIMENTS.

SEP-OCT 1981..OPTION 1: CONDUCT SMALL HILL IMPACTION STUDY NO. 2.

JUN 1982.....PRESENT MODELING CONCLUSIONS BASED ON FIELD AND LABORATORY EXPERIMENTS TO DATE.

JUL-SEP 1983..OPTION 2: CONDUCT FULL-SCALE PLUME STUDY.

AUG 1984.....PRESENT INTERIM RESULTS OF FULL-SCALE PLUME STUDY AND APPLICABLE ADAPTATIONS OF PRIOR FIELD AND LABORATORY EXPERIMENTS.

FEB 1985.....PRESENT ALL RESULTS/MODEL RECOMMENDATIONS AT SYMPOSIUM.

APR 1985.....PRESENT FINAL REPORT TO EPA.

3. SUMMARY

The EPA Program for dispersion model improvement/development for large sources in complex terrain is focused at this time on stable plume impaction on elevated terrain, with subsequent attention to other important plume phenomena. The emphasis is on models that are practical to apply in terms of computer resources and required input information, that have defined reliability and applicability. The models will be used to evaluate compliance with air quality regulations. The approach to achieving our objective is through an integrated program of model evaluation/improvement, laboratory scaled physical modeling experiments, and field studies/experiments of plume-terrain interactions on obstacles of progressively increasing size and complexity. We expect the modelers to provide leadership throughout this program.

We believe we have a reasonable program plan that has a high priority of success. The results should provide significant benefits to all parties that are concerned with satisfying air quality regulations. We intend to pursue our program vigorously.

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